

# Monitoring and characterizing offshore wind variability with weather radars for wind energy applications

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# Monitoring and characterizing offshore wind variability with weather radars for wind energy applications

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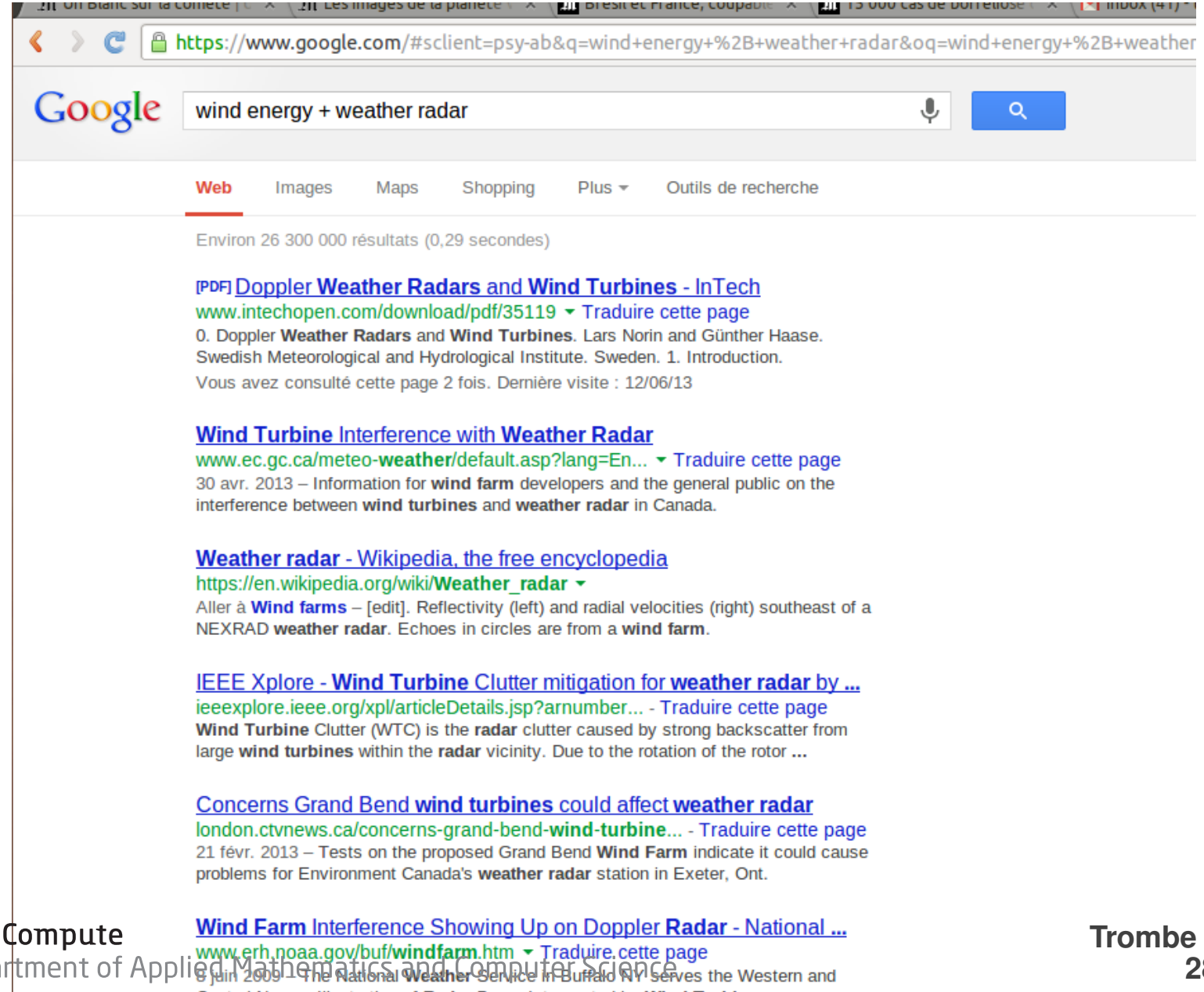
# Google search: “wind energy + weather radar”



# Building wind power forecasts – The Danish offshore experience

OBSERVATIONS → MODELING (NWP models) → POST-PROCESSING (Statistics) → INTEGRATION (Decision-making)

(summarized) DIALOGUE

- **wind farm operator (wfo)**: "I observe significant differences in wind power variability onshore and offshore. How come such differences?"

- **meteorologist**: "This is because of large offshore wind farm layout concentrating many wind turbines within a small geographical area. There is no smoothing effect!"

- **meteorologist**: "But not only. Offshore wind dynamics are also very different owing to enhanced convection over waters."

- **wfo**: "It is true. I often observe very intense rain showers during episodes of large wind (power) fluctuations."

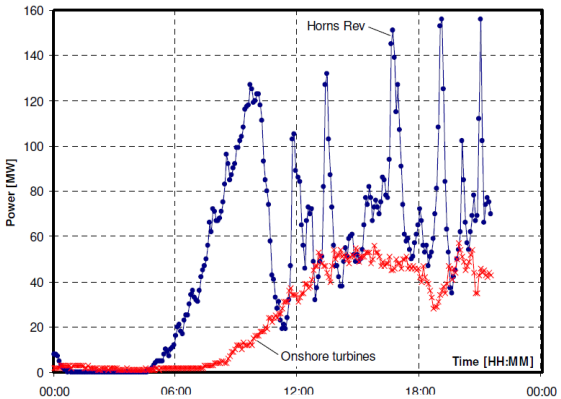
- **statistician**: "I don't understand the causes but wind time series show very sudden changes in variability."

- **meteorologist**: "I performed a mesoscale analysis of the weather and I also noticed that enhanced wind fluctuations are often correlated with the occurrence of heavy precipitation in the vicinity of the wind farm. "

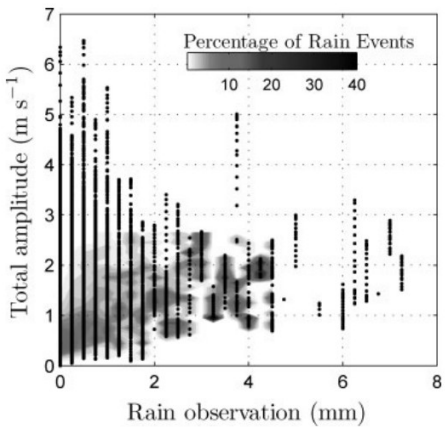
- **wfo**: "Can you provide me with new/specific wind power forecasts so that I can better handle these situations? "

- **meteorologist**: "I could use a weather radar to monitor weather conditions in the vicinity of the wind farm and assimilate precipitation data into a local NWP models."

- **statistician**: "I could ultimately develop regime-switching models based on the NWP forecasts and the information provided by the weather radar. "




(Source: *Kristoffersen* (2005))

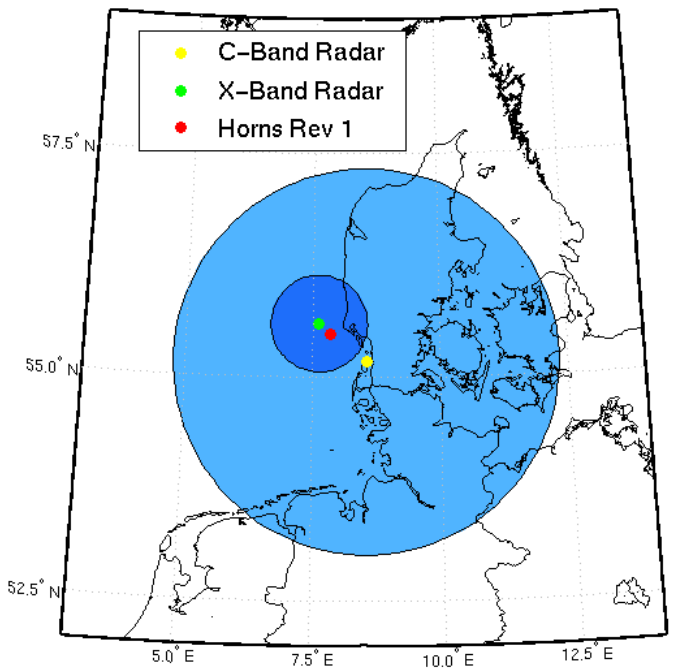



(Source: *Vincent et al.* (2011))

# Radar@Sea (2009-2012) – Partners

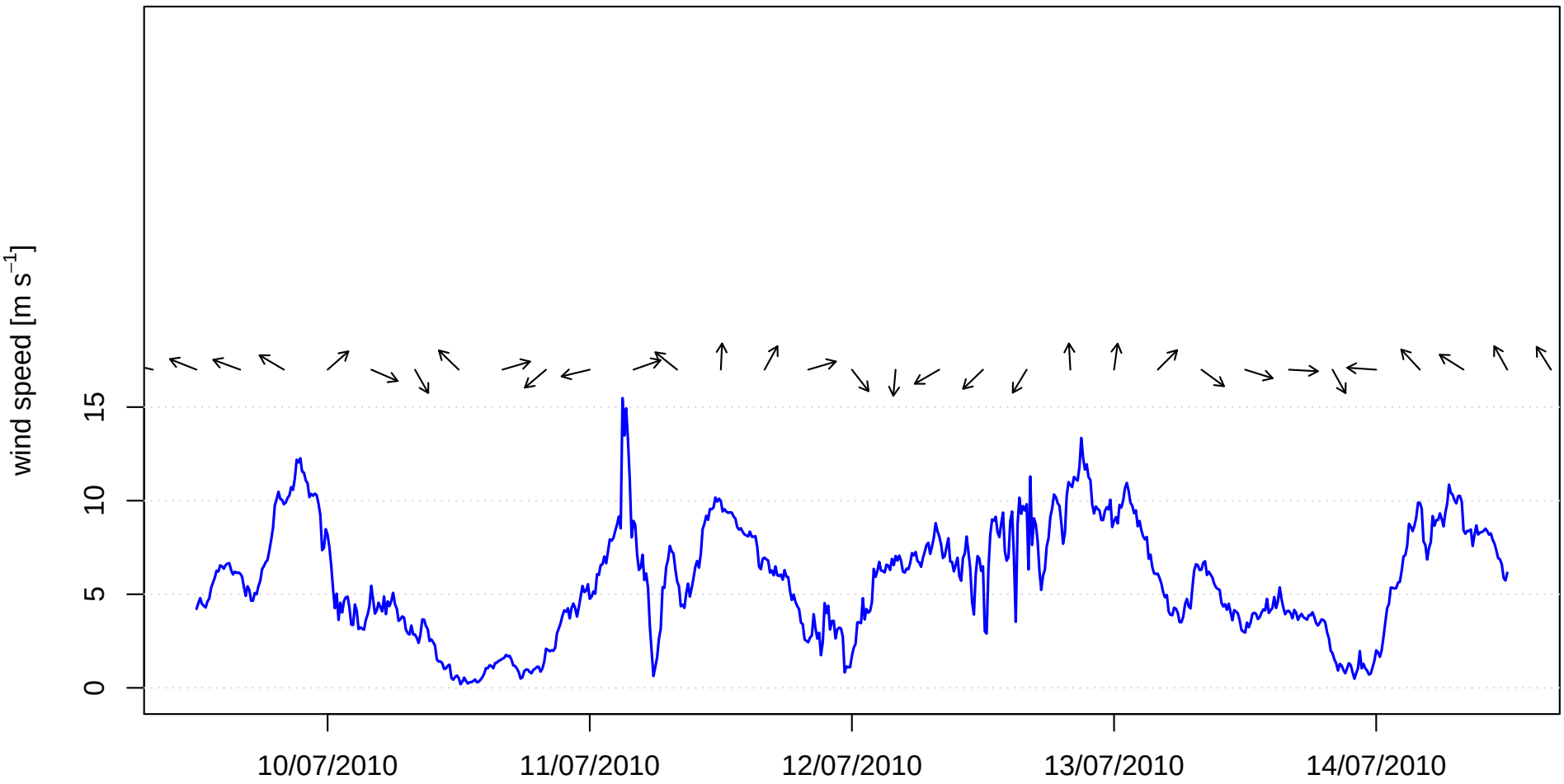
# Experimental design

| | ● LAWR (X-Band) | ● Doppler (C-Band) |
|---|---|---|
| Location | Offshore (∼15 km from HR1 ●) | Onshore (∼70 km from HR1 ●) |
| Range | small | long |
| Spatial resolution | fine | coarse |
| Temporal resolution | high | low |



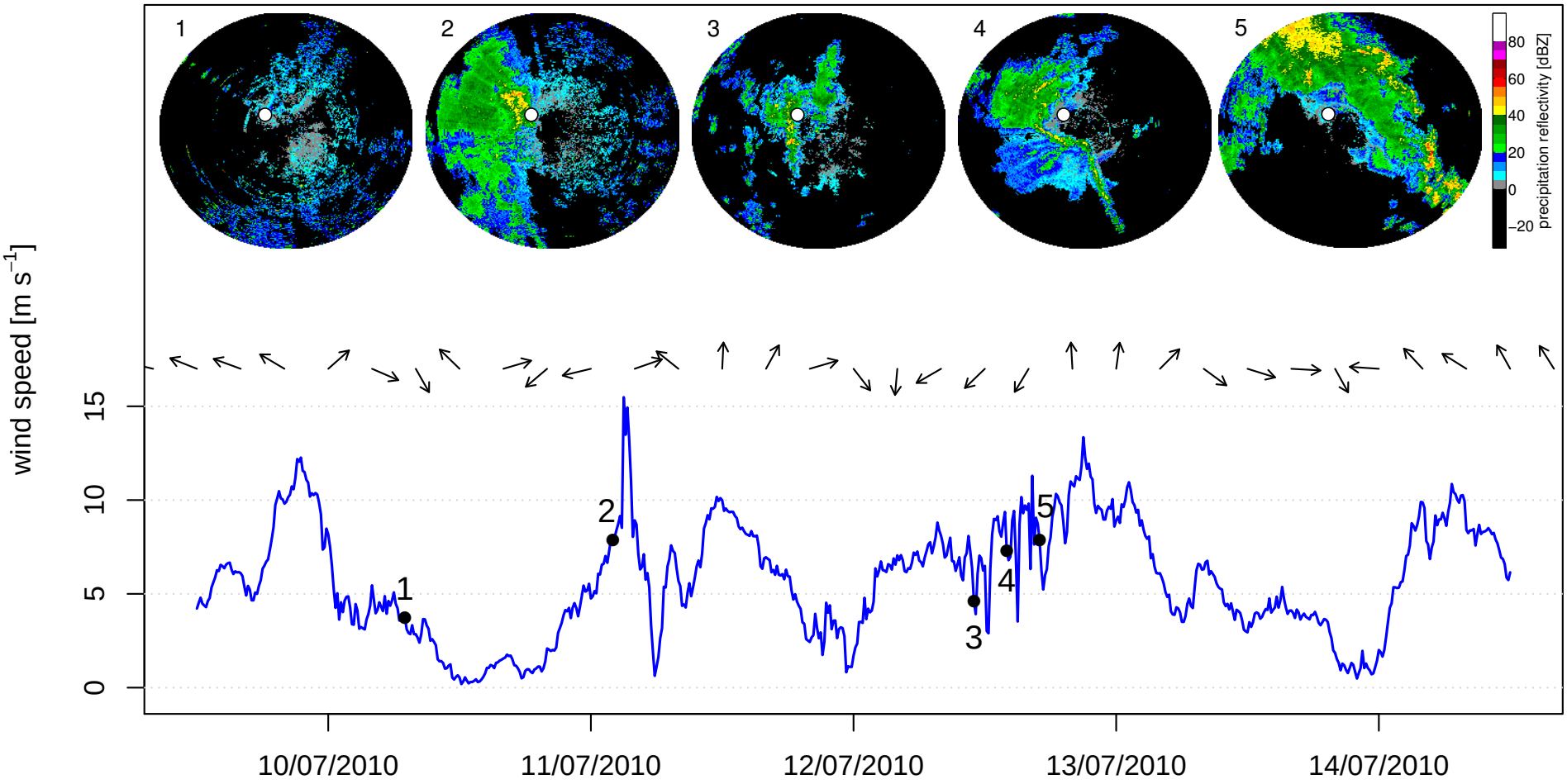

X-Band radar at Horns Rev

# Data example: Summer season



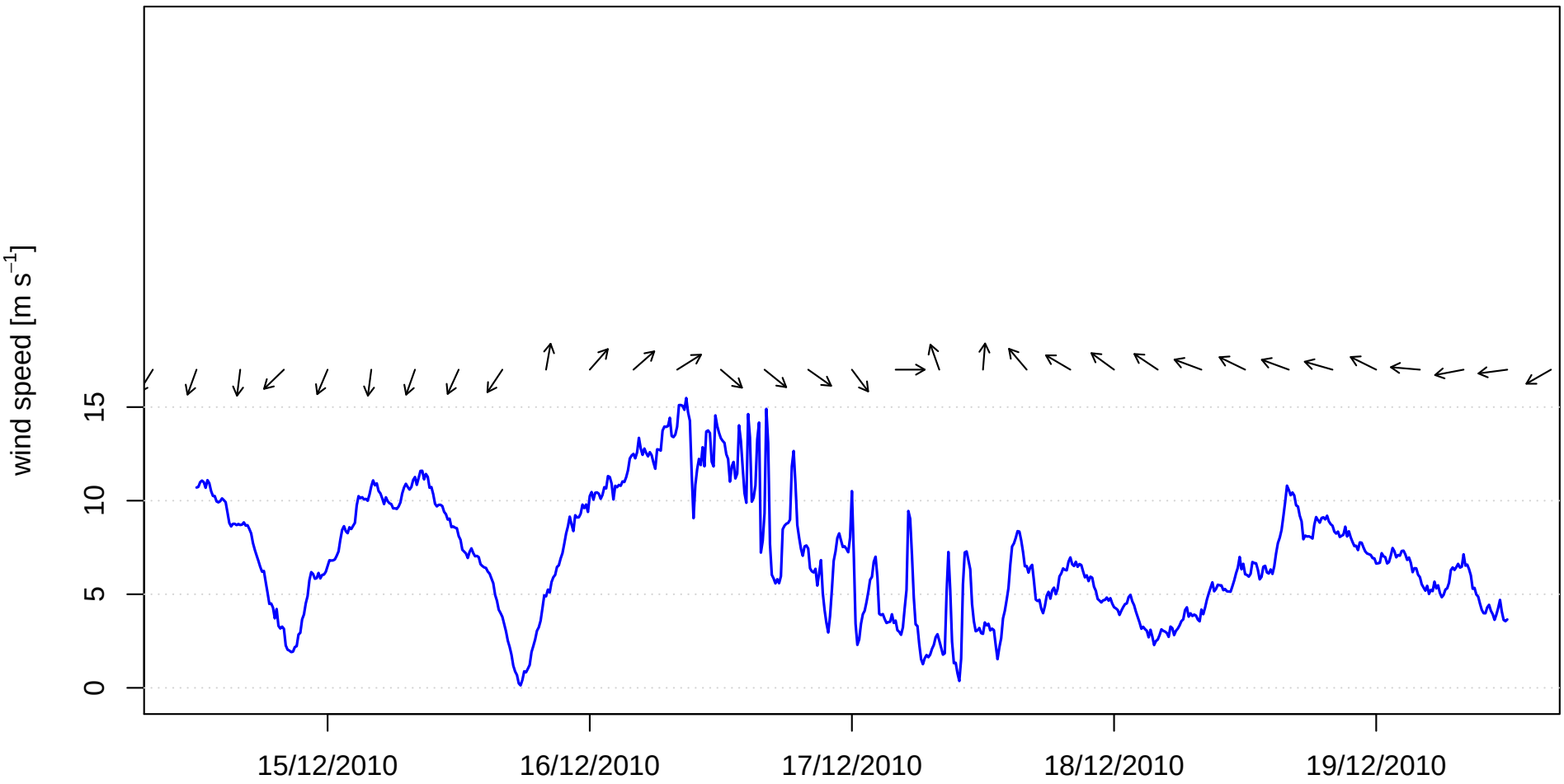

[video (click here)]

# Data example: Summer season



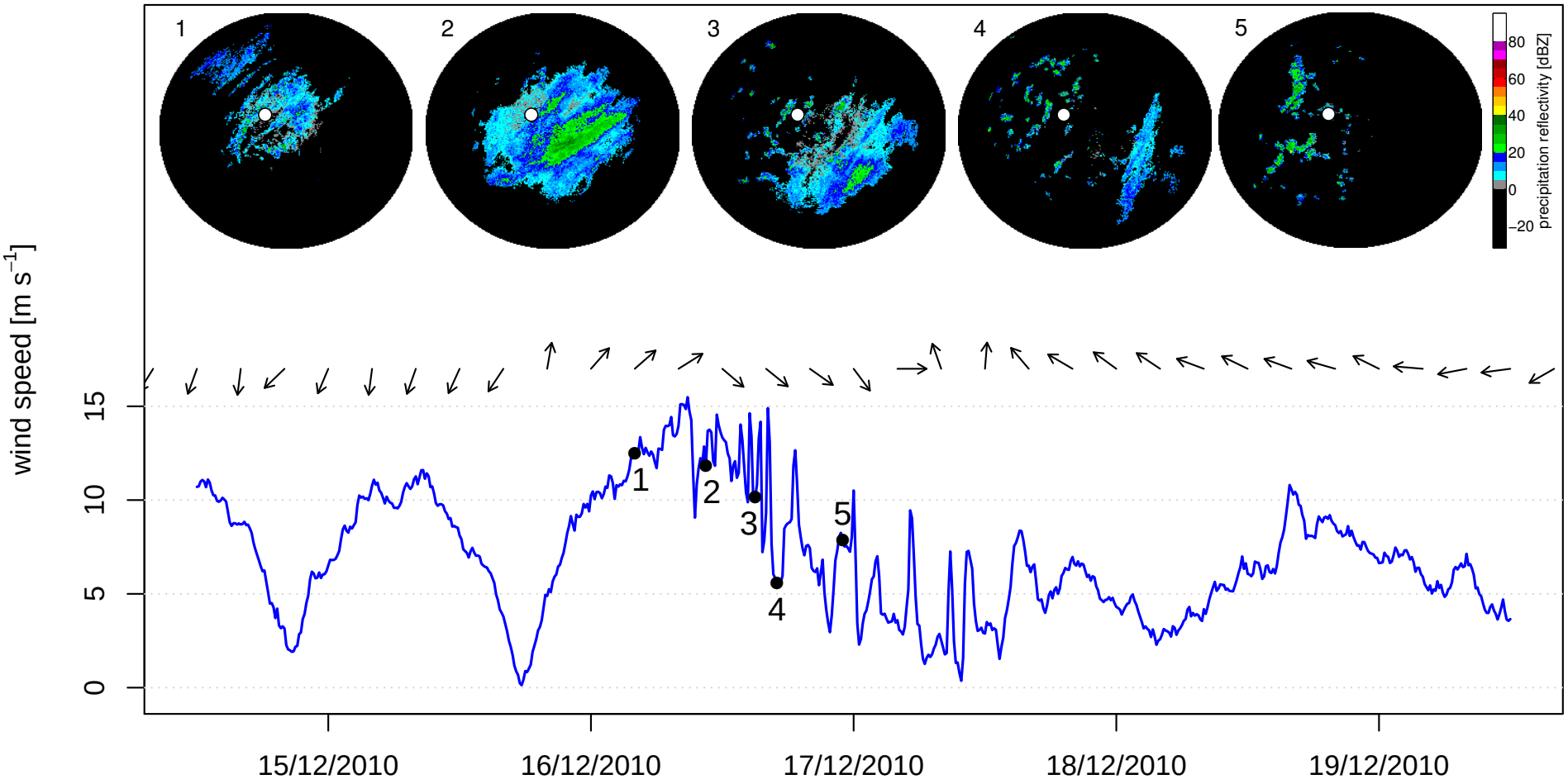

[video (click here)]

# Data example: Winter season



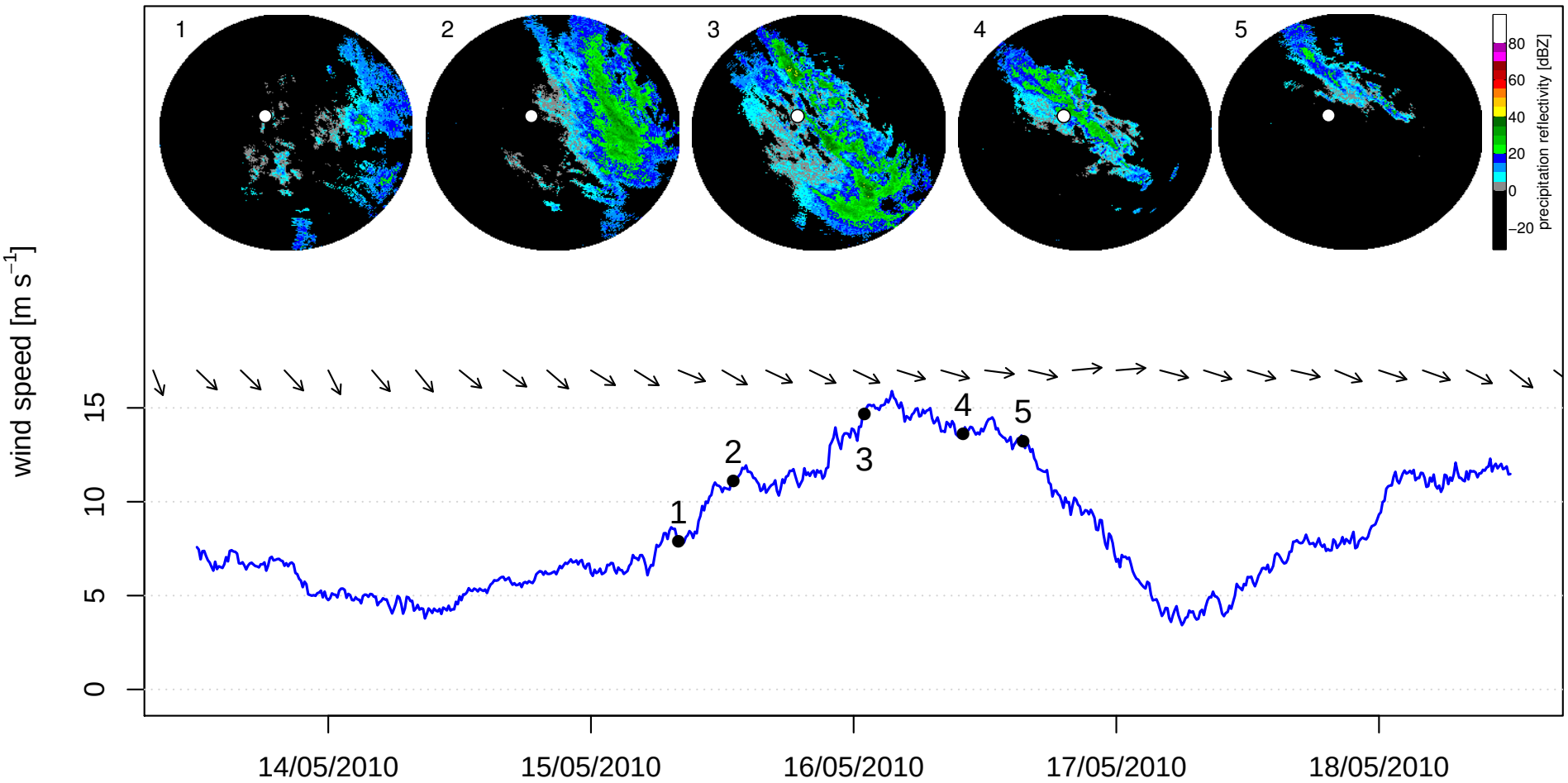

[video (click here)]

# Data example: Winter season




[video (click here)]

# Data example: Spring season




[video (click here)]

# Status & Goals

- The assimilation of weather radar data (Doppler C-Band) into a local NWP models has just started,
- So far, most work consisted of data mining (i.e, explorative analysis of the data with statistical tools):
  - objective: improve the understanding of offshore wind speed variability with the information extracted from weather radar observations,
  - initial focus on the observations produced by the Doppler C-Band,
  - develop automatic procedure (with very little knowledge expert)
- Present results in a easy-to-interpret manner:
  - graphic based,
  - low dimensional outputs.

# Wind speed variability index

- **Time series segmentation**
  Markov-Switching model + Global Decoding algorithm = categorical index

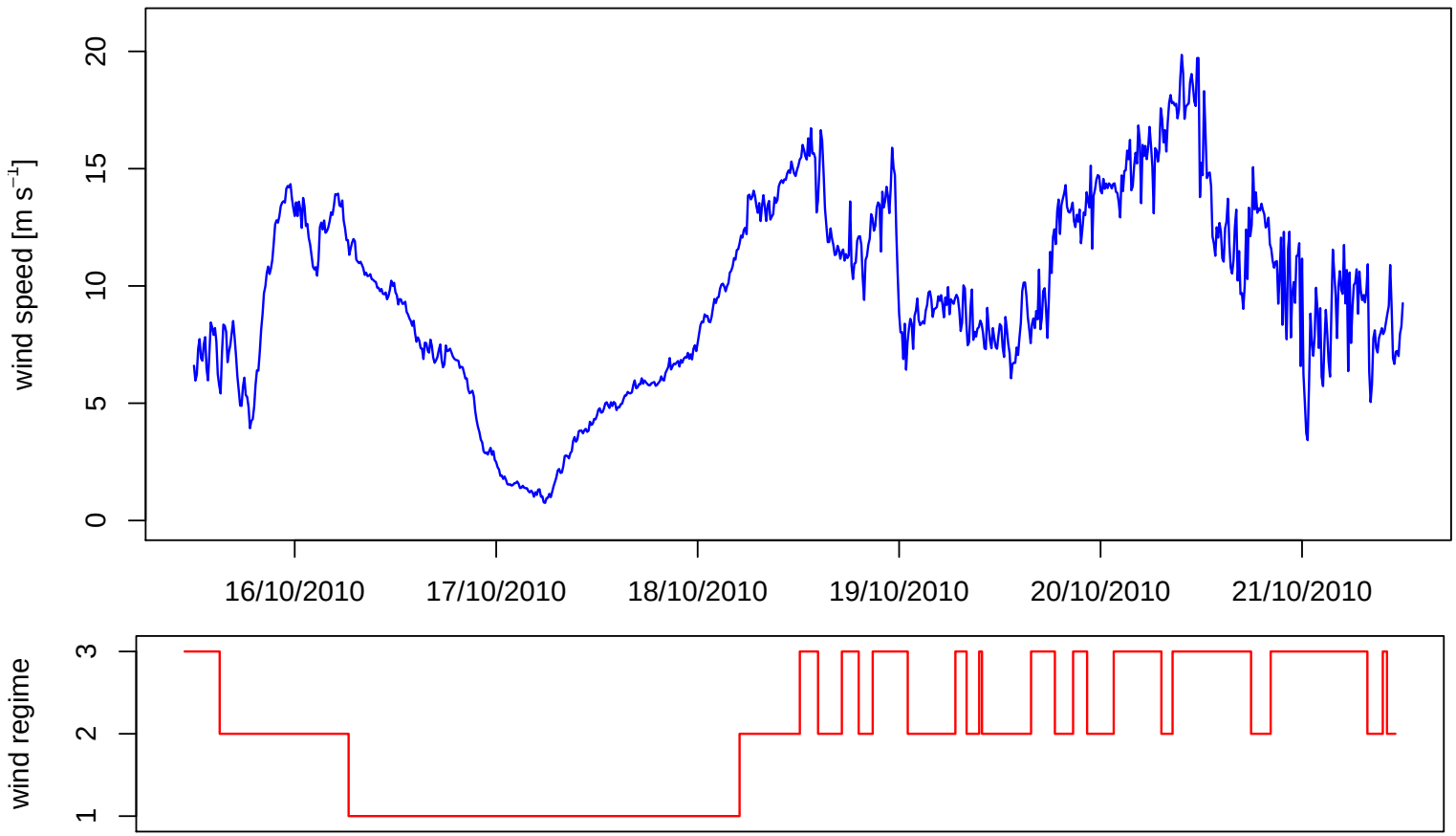



**Figure:** Segmenting into 3 regimes

# Wind speed variability index

- **Time series segmentation**
  Markov-Switching model + Global Decoding algorithm = categorical index

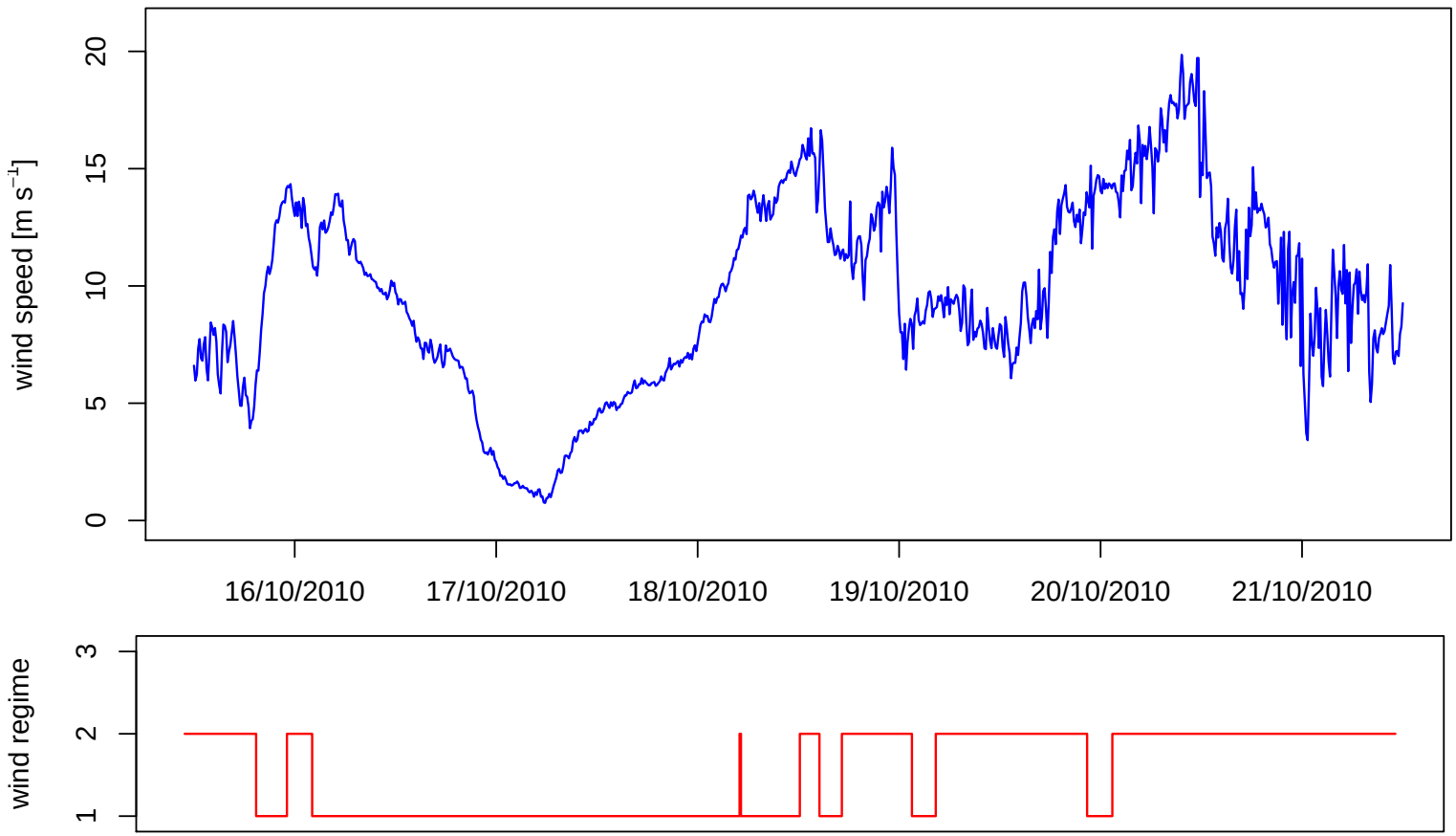



**Figure:** segmenting into 2 regimes

# Wind speed variability index

- **Time series segmentation**
  Markov-Switching model + Global Decoding algorithm = categorical index

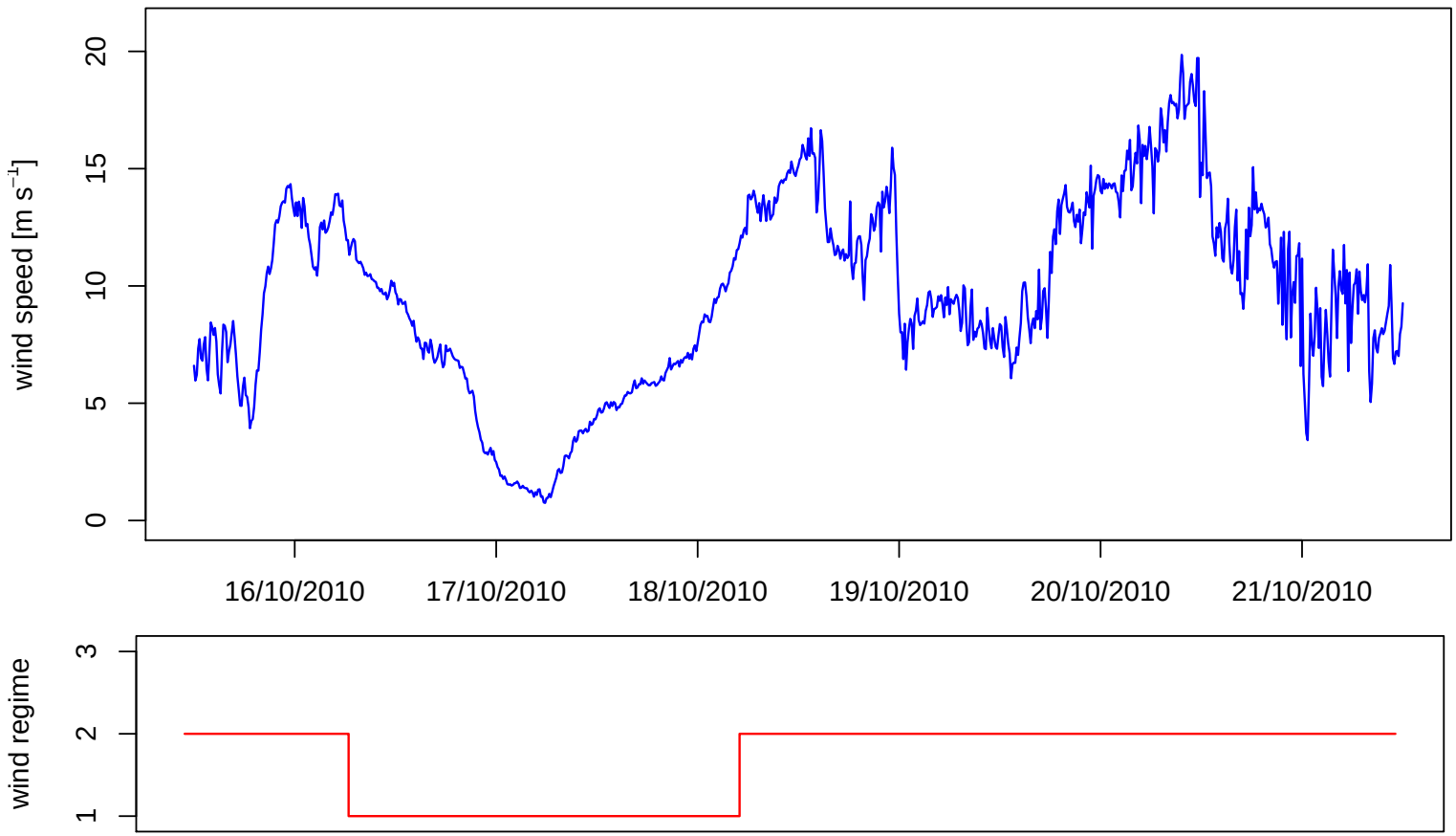
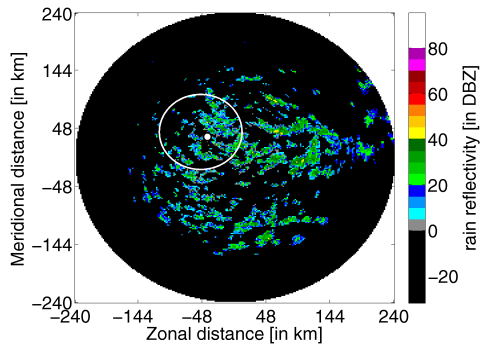



**Figure:** Segmenting into 3 regimes initially but merging regimes #2 and #3

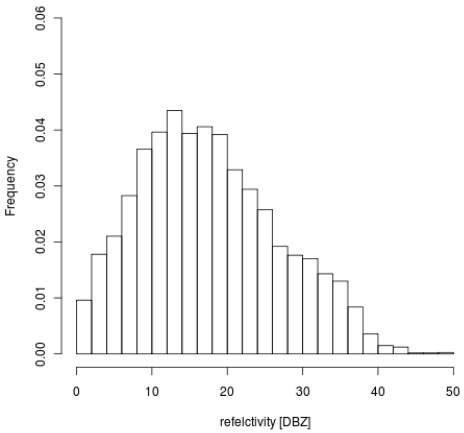
# Global attributes from weather radar images



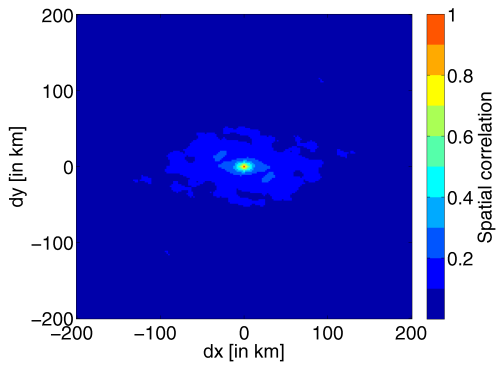

Reflectivity distr.

Spatial Continuity

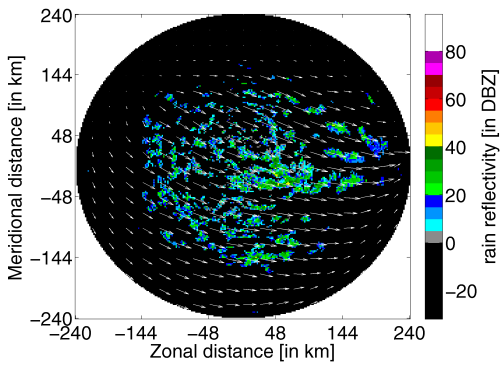
Motion




median, quantile 99% (robust estimator of maximum value), . . .



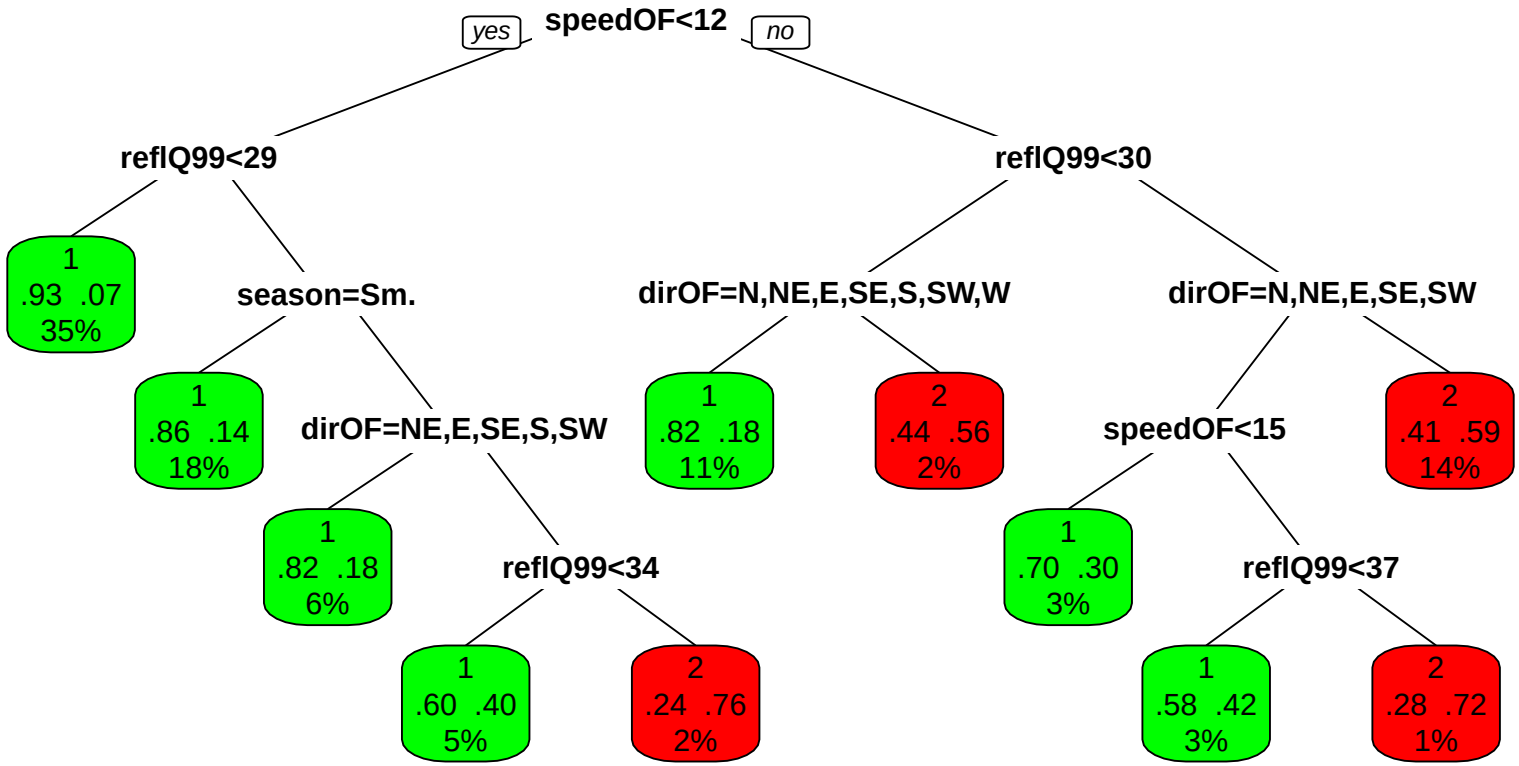

Area & Ellipticity




Speed & Direction

# Wind variability classification

- Method: Classification and Regression Trees (CART)




- learning #1: importance of particular attributes (speed, direction and max reflectivity),
- learning #2: we connot go global, need for local attributes.

# Conclusion

- There is a mutual interest for weather radar and wind energy communities to collaborate,
- Methodological proposal for mining offshore wind farm and weather radar data (with focus on visual representation of the results),
- Confirmation of previous results [*Vincent et al.* (2011)],
- Statistical and data mining tools can help revealing interesting insights on meterological data for energy applications,
- Future work:
  - consider 3D weather radar observations + radial winds
  - time series analysis over multis-cale,
  - object identification on weather radar images (e.g, small convective cells and storms)
  - consider other meteorlogical inputs (e.g. met. forecasts from NWP models, satellite images),
  - integrate weather radar data into a prediction system.

# Thank you for your attention!

## References and further reading:

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